Chapter 31

Criticality Safety

June 1997

Approved by the ES&H Working Group

____ **date** _____________

Robert Kuckuck
Deputy Director for Operations

31

Criticality

Contents

*** Revised**

31

Criticality

31.1 Introduction

LLNL policy mandates that fissionable materials shall be handled, processed, stored, and transported such that the probability of an accidental criticality is extremely low. This chapter describes the LLNL criticality safety program.

31.2 Applicability

This chapter applies to personnel, activities, and equipment involving significant quantities of fissionable materials. All personnel who work with or who are responsible for managing activities involving significant quantities of fissionable materials must comply with the requirements in this chapter.

31.3 Requirements/Regulatory Summary

All activities involving significant quantities of fissionable material shall comply with DOE Order 5480.24, "Nuclear Criticality Safety," (latest edition, or replacement) and shall be conducted in accordance with the appropriate ANSI/ANS nuclear criticality safety standards specified in Section 31.8.

31.4 Process for Risk Reduction

Criticality safety is a key element in the Laboratory's Environmental, Safety, and Health (ES&H) Program (UCRL-AR-119618). The principal objective of the criticality safety program is to ensure that the likelihood of an accidental criticality is extremely low when processing, storing, or transporting fissionable materials. Specific requirements and guidance on criticality safety are provided in the following sections.

31.4.1 Safety Procedures

Activities involving significant quantities of fissionable materials shall be authorized by an approved safety procedure governing both the material involved and the operations (see Sections 31.4.4 and 31.4.5). The safety procedure shall specify all criticality safety controls and the criticality hazard type (see Section 31.4.11 for details). Criticality safety controls may include

- Fissionable material mass limits.
- Liquid volume limits.
- Moderator and reflector restrictions.

- Geometry controls.
- Physical and chemical form controls.
- The minimum spacing between adjacent workstations (if applicable).

The safety procedure must be approved in accordance with Chapter 2 of this Manual, and all controls must be in place before the operation can begin. Changes to a safety procedure that may affect criticality safety must be reviewed by the appropriate ES&H team.

31.4.2 Safety Analyses

When required, safety analysis documents such as Preliminary Hazards Analyses (PHAs), Safety Analysis Reports (SARs), and Technical Safety Requirements (TSRs) shall be reviewed for criticality safety by the appropriate ES&H team if such documents pertain to activities involving significant quantities of fissionable materials.

31.4.3 Criticality Safety Evaluations

Some facilities and operations may proceed if they satisfy the controls and limits specified in Section 31.4. Other activities will require a criticality safety evaluation specific to the facility or operation. Figure 31-1 is provided as aid in determining the requirement for an operation- or facility-specific criticality safety evaluation.

For activities requiring a criticality safety review, the ES&H team shall ensure that a criticality safety evaluation is performed and documented to determine that the entire activity will remain subcritical under all normal and credible abnormal conditions. Operational controls for work involving significant quantities of fissionable materials shall satisfy the "Double Contingency Principle," which states that "process designs *shall* incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible."

Special Concerns. Certain activities are of special concern to criticality safety because they may have the potential for achieving a minimum critical mass. These are activities that include

- Fissionable material in gaseous form.
- Fissionable material at cryogenic temperatures.
- Fissionable material dispersed in a matrix or intimately mixed with hydrogenous materials having a hydrogen density greater than that of water (e.g., polyethylene or oils).
- Fissionable material intimately mixed with or in close proximity to beryllium, graphite, deuterium or their compounds.

These activities require review by the ES&H team on a case-by-case basis. Any questions about whether a specific activity requires a criticality safety review should be referred to the appropriate ES&H team.

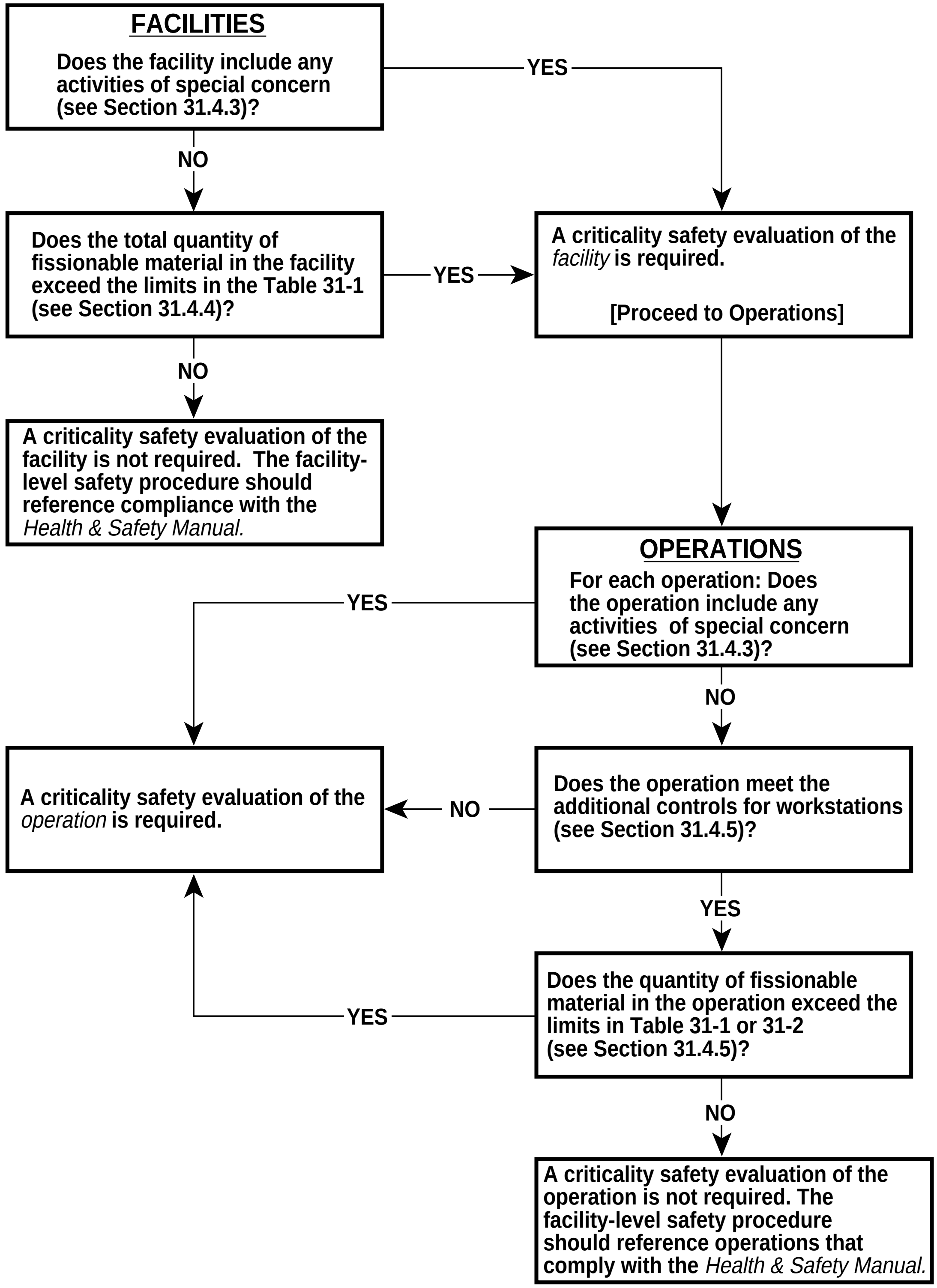

Figure 31-1. Guidance for determining if a criticality safety evaluation is required for facilities and operations.

31.4.4 Criticality Safety Mass Limit Guidelines for Facilities

Any combination of isotopes listed in Table 31-1 on the following page may be permitted in a facility provided the following criterion is satisfied:

$$\sum_{i=1}^{N} \frac{M_i}{L_i} < 1,$$

where M_i is the total mass inventory of the i^{th} fissionable isotope and L_i is the mass limit of the i^{th} fissionable isotope. These mass limits apply to the total inventory of fissionable materials present in the facility, including materials present in sealed sources and in Type A and Type B packaging. Adherence to these limits will assure that the mass of fissionable materials present in an entire facility does not exceed a significant quantity. The mass limits in Table 31-1 are based on water moderation and do not apply to activities that involve hydrogenous materials with a hydrogen density greater than that of water (e.g., polyethylene or oils).

If a facility requires a quantity of an isotope larger than those listed in Table 31-1 or exceeds the criterion for combinations of isotopes, or if activities within a facility constitute a special concern (discussed in Section 31.4.3), then the proposed operation will require a safety procedure specifying the appropriate criticality safety controls. The proposed activity also may require additional criticality safety controls (e.g., exclusion of certain reflector materials, moderator controls, geometry controls) and establishment of a workstation (see Section 31.4.5).

31.4.5 Criticality Safety Mass Limit Guidelines for Workstations

Fissionable material mass limits for an individual activity or workstation may be based on the guidelines in Table 31-2 on the following page provided that the following additional controls are in place:

- The fissionable material is not dispersed in a matrix or intimately mixed with hydrogenous materials having a hydrogen density greater than that of water (e.g., polyethylene or oils).
- The fissionable material is not intimately mixed with or is in close proximity to beryllium, graphite, deuterium, or their compounds.
- There are no close-fitting reflector materials (such as lead, uranium, tungsten, or steel) that exceed 5 centimeters in thickness.

Activities with fissionable isotopes not included in Table 31-2 may be based on the guidelines in Table 31-1 provided that the above controls are also satisfied. Adherence to these limits and controls will assure that the mass of fissionable materials present at an individual workstation or activity does not exceed a significant quantity. If a proposed activity requires a quantity of fissionable material larger than those listed in Table 31-2, or if the controls above cannot be satisfied, then the proposed activity requires a safety procedure with a specific criticality safety evaluation and review by the ES&H team.

Table 31-1. Fissionable material mass limits for facilities.*	
Isotope	Mass limit (grams)
$_{99}Es^{254**}$, or any isotope with an atomic number >99	0.1
$_{98}Cf^{251**}$, or any unspecified isotope with an atomic number $95 \leq Z < 99$	2
$_{95}Am^{242m}$, $_{98}Cf^{249**}$	4
$_{96}Cm^{245**}$	14
$_{86}Rn^{222}$, $_{88}Ra^{223**}$, $_{88}Ra^{224}$, $_{88}Ra^{225**}$, $_{89}Ac^{225}$, or any unspecified isotope with an atomic number $88 \leq Z < 95$	15
$_{96}Cm^{243**}$	35
$_{94}Pu^{241**}$	60
$_{99}Es^{253}$	100
$_{94}Pu^{239**}$	145
$_{92}U^{233**}$	195
$_{92}U^{235**}$	290
$_{96}Cm^{247**}$	300
$_{92}U^{232}$, $_{92}U^{234}$, $_{93}Np^{235}$, $_{94}Pu^{236}$, $_{94}Pu^{244}$, $_{96}Cm^{242}$, $_{96}Cm^{246}$, $_{96}Cm^{248}$, $_{97}Bk^{249}$, $_{98}Cf^{250}$, $_{98}Cf^{252}$	500
$_{94}Pu^{238}$, $_{96}Cm^{244}$	1,000
$_{91}Pa^{231}$, $_{95}Am^{243}$, $_{93}Np^{237}$, $_{94}Pu^{240}$, $_{95}Am^{241}$	10,000
$_{94}Pu^{242}$	18,000
Natural or depleted uranium	36×10^6
$_{88}Ra^{226}$, $_{89}Ac^{227}$, $_{90}Th^{228}$, $_{90}Th^{229**}$, $_{90}Th^{230}$, $_{90}Th^{232}$, $_{92}U^{236}$, $_{92}U^{238}$, $_{92}U^{240}$, $_{93}Np^{239}$, or any isotope with an atomic number <88	Unlimited

∗ Also see 31.4.6 for isotopic mixtures and Section 31.4.3 for criticality safety evaluation requirements.
** Fissile isotopes.

Table 31-2. Fissionable material mass limits for workstations.*	
Isotope	Mass Limit (grams)
$_{94}Pu^{239}$	220
$_{92}U^{233}$	250
$_{92}U^{235}$	350
Any combination of $_{94}Pu^{239}$, $_{92}U^{233}$, or $_{92}U^{235}$	220*

∗ Also see 31.4.6 for isotopic mixtures and Section 31.4.3 for criticality safety evaluation requirements.

Facilities containing significant quantities of fissionable materials may be divided into a number of workstations for administrative and physical control of the fissionable material. Unless otherwise stated in a safety procedure, workstations shall have the following controls:

- The spacing between adjacent workstations shall be sufficient to control neutron interaction between fissionable materials. The recommended minimum spacing is 16 inches edge-to-edge and shall not be less than 12 inches.
- Workstations shall be limited to planar arrangements and shall not be arranged to constitute an effective volume array.

Modifications to a workstation that include changes to the physical geometry or addition of significant quantities of equipment or materials require a criticality safety review by the appropriate ES&H team. These materials include but are not limited to polyethylene, concrete, steel, tantalum, tungsten, and beryllium.

Box Loss. For many operations, the mass of the fissionable material removed from the workstation after an operation is less than that introduced before the operation. This difference is assigned to “box loss.” By definition, all box loss is considered to be dispersible fissionable material (see Appendix 31-A). The amount of box loss assigned to a workstation can be reduced by cleaning the workstation to remove or recover any measurable amount of fissionable material. The amount of fissionable material remaining after the workstation is cleaned is assumed to be negligible. The box loss for that workstation is then considered to be “zero” for criticality safety purposes.

31.4.6 Criticality Safety Mass Limit Guidelines for Isotopic Mixtures

Fissionable materials are not normally isotopically pure because they contain varying amounts of other fissionable or fissile isotopes. The subsections below provide guidance for several fissionable material mixtures commonly used at LLNL.

Weapons Grade Plutonium. The mass limits for isotopically pure ^{239}Pu are applicable to the sum of the masses of ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, and ^{241}Am in an isotopic mixture of plutonium provided the isotopic concentration of ^{240}Pu exceeds that of ^{241}Pu and ^{241}Am combined, and all isotopes are considered to be ^{239}Pu in computing mass. Thus, the ^{239}Pu mass limit may be applied to elemental plutonium for typical weapons grade plutonium.

^{238}Pu. The mass limits for isotopically pure ^{238}Pu may be applied to an isotopic mixture of ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, and ^{241}Am provided the plutonium contains at least 67% ^{238}Pu and the isotopic concentration of ^{241}Pu and ^{241}Am is less than that of ^{240}Pu.

Enriched Uranium. The mass limits for isotopically pure ^{235}U may be applied to isotopic mixtures of ^{234}U, ^{235}U, ^{236}U, and ^{238}U of any enrichment provided that ^{234}U is considered to be ^{235}U in computing the mass.

^{233}U. The mass limits for isotopically pure ^{233}U may be applied to isotopic mixtures of ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U of any concentration provided that ^{234}U and ^{235}U are considered to be ^{233}U in computing the mass.

Natural Uranium and Depleted Uranium. Natural uranium consists of elemental uranium containing 0.7% by weight of the fissile isotope ^{235}U. Depleted uranium consists of elemental uranium containing less than 0.7% by weight of ^{235}U. Natural and depleted uranium may be authorized in unlimited amounts provided the uranium is not intermixed or placed in close proximity to hydrogen, beryllium, deuterium, carbon, or their compounds. Activities with natural or depleted uranium exceeding 36,000 kg shall be reviewed for criticality safety by the ES&H team.

31.4.7 Storage

Storage of significant quantities of fissionable material is subject to the same restrictions and requirements as any other activity involving fissionable material. Specific storage criteria for each facility shall be defined in a safety procedure, which shall include the following criticality safety controls, as appropriate:

Physical Controls

- Requirements specifying approved container types.
- Requirements for physical barriers to maintain a safe spacing between fissionable material containers.

Administrative Controls

- Fissionable material mass limits for each storage location, storage array, and/or room.
- Posting requirements.
- Requirements for the maintenance of inventory listings for fissionable material in each storage container, storage location, storage array, and/or room.

31.4.8 Shipping and Transfer

The Materials Management Section (MMS) shall prepare fissionable materials for offsite shipment and transfer the material onsite between facilities. The Hazardous Waste Management Division shall prepare waste containing fissionable materials for offsite shipment or onsite transfer between facilities. For further details, see Chapter 8 of this Manual, the *Materials Control and Accountability Program Manual*, and the *Onsite Hazardous Materials Packaging and Transportation Safety Manual*.

Offsite Shipment. Fissionable materials shall be packaged and transported in a manner that will prevent a criticality accident. The shipment shall be maintained in its original approved condition during transport, and any special restrictions shall be communicated to the driver or other responsible persons.

Approved DoD, DOE, DOT, and NRC packages shall be shipped in accordance with federally approved standards (e.g., TP-20-7, offsite transportation certificate, Code of Federal Regulations). Some shipments may require a criticality safety statement or a one-time shipping request. A criticality safety statement may be obtained from the ES&H team upon request.

Transport of NELAs. Nuclear Explosive-Like Assemblies (NELAs) containing "mock" high explosive and "live" fissionable materials shall be shipped in DoD shipping containers in accordance with TP-20-7 requirements or have the appropriate criticality safety statement for the corresponding warhead.

Onsite Shipments between Facilities. Fissionable materials to be transported onsite between facilities shall be either

- Packaged and transported in accordance with approved DoD, DOE, DOT, or NRC regulations for offsite shipments; or
- Packaged and transported in accordance with an approved safety procedure or an approved onsite transportation safety manual that has been reviewed for criticality safety by the appropriate ES&H team.

Onsite Transfers within Facilities. Fissionable materials to be transferred within facilities shall be packaged and transported in accordance with an approved safety procedure that has been reviewed by the ES&H team for criticality safety. The procedure shall include

- Requirements specifying approved container types.
- Requirements for maintaining a safe spacing between fissionable material in transit and all other nearby fissionable material.
- The fissionable material mass limits for each transport movement.
- Limits for the maximum number of simultaneous transfers.
- Posting requirements.
- Designation of responsible personnel.

31.4.9 Audits and Inspections

Formal Activity Audits. At least once a year, every onsite facility with the potential for a criticality accident shall be audited. The audit shall be coordinated by Hazards Control. Such criticality safety audits should be performed by recognized criticality safety experts who are independent of the activity. These audits are conducted to verify that applicable safety procedures, standards, and DOE orders are being followed, and to confirm the adequacy of criticality safety controls. Any criticality safety deficiencies identified during an audit must be addressed by the responsible manager. Guidance for performing criticality safety audits may be found in *LLNL Criticality Safety Audits* (UCRL-MA-110583, Parts 1 and 2).

A copy of the criticality safety audit report shall be sent to the appropriate line management through the AD level, the AD for Plant Operations, and the Assurance Review Office.

Criticality Safety Inspections. Informal inspections and “walk-throughs” may be performed by ES&H team members and by the Criticality Safety Group personnel at any time. Criticality safety deficiencies identified during such inspections will be brought to the immediate attention of the ES&H team leader and the facility manager for resolution.

31.4.10 Violations of Criticality Safety Controls and Limits

A criticality safety control violation is defined as any deviation from safety procedures that may adversely affect the criticality safety of any activity involving fissionable materials. This includes violations of criticality safety mass limits, moderator limits, or any other controlled parameters. Situations that constitute reportable violations and actions, as specified in Table 31-3, may be defined in the facility safety procedure.

All violations shall be reported immediately to facility management and the ES&H team, and must be evaluated promptly.

Response to Violations. Table 31-3 contains a listing of the actions to be taken if a criticality safety control or limit violation is found or suspected.

Reporting Violations. After recovery from a violation of a criticality safety control or limit, the facility manager shall prepare a formal memorandum summarizing the infraction and lessons learned. This report shall specify any actions required to preclude a recurrence. A copy of the report shall be provided to the Criticality Safety Group. The facility manager shall also comply with any additional reporting requirements, as described in the LLNL Implementing Procedure for DOE Order 232.1, and the Price-Anderson Amendments Act Non-compliance Reporting Guidelines, as applicable.

31.4.11 Criticality Accidents

Criticality accidents shall be investigated and reported in accordance with current LLNL policy. Refer to Chapter 4 of the *Health & Safety Manual* for details.

The following subsections describe procedures and mitigating features designed to mitigate the consequences of a criticality accident.

Criticality Alarm System (CAS). Each facility or activity involving the use of fissionable materials outside of sealed containers and exceeds 700 g of ^{235}U, 520 g of ^{233}U, or 450 g of ^{239}Pu shall be evaluated to determine if a criticality alarm system (CAS) is required. This system shall be capable of activating an Immediate Evacuation Alarm (IEA) that is audible throughout the facility (see Chapter 11 of this Manual and ANSI/ANS-8.3). Each facility or activity that requires a CAS shall hold an evacuation exercise at least once a year. This exercise shall be announced in advance.

Table 31-3. Actions required for violations of criticality safety controls or limits.	
Condition	**Actions**
A violation of a criticality safety control or limit is found or suspected to have occurred.	• Suspend all affected activities immediately and, if it is safe to do so, place these activities in a safe static situation (i.e., where the form and geometry of the fissionable material remain unchanged). • Leave the immediate area and prevent others from entering within 15 ft of the fissionable material, if possible. • Report the suspected violation to the appropriate supervisor and facility manager.
The activity has been safely suspended and placed in a safe static situation.	• Personnel shall be prevented from entering the area within 15 ft of the fissionable materials. • The facility manager shall contact the ES&H team criticality safety experts regarding the incident. • A recovery plan mutually acceptable to criticality safety experts and the facility manager shall be developed and recovery carried out according to the plan.
The activity cannot be safely suspended.	• The supervisor and/or senior operator shall decide whether to stop the activity or evacuate the immediate area, or both. This decision shall be based foremost on the consideration of their own safety, the safety of others, and whether the process will evolve into a more dangerous situation if permitted to proceed. • The facility manager shall determine any subsequent course of action with consultation from criticality safety experts at the earliest opportunity.

If a required CAS is not fully operational, all work with fissionable materials in the affected areas shall be stopped and all fissionable material operations in progress shall be brought to a safe "stand-by" condition. The facility manager shall inform all facility personnel of the work stoppage and when work can be resumed.

Response to an Immediate Evacuation Alarm. If the IEA activates, all personnel shall immediately leave the building and report to the designated assembly area. The following shall be done at the assembly area:

- The facility manager (or designee) shall ensure (by "head count") that all personnel have left the facility.
- The ES&H team and the facility manager shall determine the cause of the alarm before normal operations can begin.
- The ES&H team shall survey all individuals to determine if they were exposed to radiation. (This survey shall be governed by the circumstances leading to the evacuation.)
- Evacuated personnel shall remain in the assembly area until directed otherwise by facility management.
- The incident commander shall direct recovery operations if the IEA is activated (see Chapter 3 of this Manual for further details).
- The ES&H team shall authorize re-entry to the facility only after verifying that the likelihood of a recurrence (spontaneous or otherwise) of a critical condition is remote.

If a criticality accident has occurred, re-entry into the facility shall be granted only by authorized personnel and governed by the authorized radiation dose limits that a rescuer may receive during an emergency (see Supplement 33.03 of the *Health & Safety Manual* for details).

Nuclear Accident Dosimeters (NADs). NADs are located in fixed locations throughout nuclear facilities with a potential for a criticality accident. Placement of NADs within a facility allows for assessment of the radiation dose and spectral characteristics resulting from a criticality accident. NADs are unobtrusive, require no routine maintenance, and may provide vital information in determining the levels and extent of medical treatment for injured personnel. NADs shall meet the requirements of ANSI/ANS-N13.3, "Dosimetry for Criticality Accidents." The specific locations of all NADs within a facility will be formally documented and maintained by the facility manager.

Fire-Fighting Guidelines. The possibility of a criticality accident may increase if water or other moderating materials are used to fight fires involving fissionable materials. Because of this concern, safety procedures shall describe the fire hazards associated with the materials used in experiments or operations. Examples of fire hazards include

- Fire in an area where a container of fissionable materials has ruptured or opened.

- Fire in a glove box where fissionable materials are handled, processed, or stored.
- Fire involving pyrophoric fissionable materials (e.g., metal fines, chips, or hydrides).

Operations personnel shall consult with fire safety personnel to identify credible fire hazards involving fissionable materials for a planned activity. The approved safety procedure for each operation shall include the criticality hazard type assigned to the operation as well as any unique or unusual responses in the event of a fire.

The definitions for the criticality hazard types are

Criticality Hazard Type 1. Water may be used as required. Total flooding will not cause a criticality incident. Handle as any radioactive material fire.

Criticality Hazard Type 2. Water is allowed only if fissionable materials are not involved in the fire or they can be safely removed (or isolated) from the fire.

Criticality Hazard Type 3. Water is not allowed.

Criticality Hazard Type 1 shall be assumed if a classification is not listed in the authorized safety procedure for a workstation or activity. The facility manager shall assure that fire safety personnel are informed of all Criticality Hazard Types 2 and 3 for incorporation into emergency response procedures. All Criticality Hazard Types 2 and 3 shall be posted within the facility, as appropriate.

For more details on how to respond to fires in glove boxes, see Chapter 3 of this Manual and the applicable safety procedure.

31.5 Responsibilities

The following sections describe roles and responsibilities for the criticality safety program as an element of the Laboratory's integrated ES&H Program.

31.5.1 Basic

The primary line of responsibility for criticality safety with regard to fissionable material extends from the Laboratory Director through the Program and Facility AD(s) to authorized users who have hands-on responsibility for activities involving fissionable material. These responsibilities are detailed in Sections 31.5.2 and 31.5.3. The Laboratory Director also assigns responsibility for the institutional aspects of criticality safety through the AD for Plant Operations to Hazards Control. These responsibilities are described in Section 31.5.4.

31.5.2 Facility

Within the facility where the activities are to be conducted, the line of responsibility extends from the Facility AD to the facility manager who is directly responsible for the safe operation of the facility including criticality safety, facility safety analyses, unreviewed safety question determination, and facility training. The Facility AD (or designee) is also responsible for developing and approving the facility safety procedure (FSP) for that facility. The Facility AD's approval signifies that the activity complies with LLNL's ES&H policies and that line management accepts the residual risk. The FSP and Chapter 2 of the *Health & Safety Manual* define the circumstances under which a proposed operation requires an operational safety procedure (OSP). All activities involving fissionable material in quantities where a criticality might occur must be covered by a safety procedure.

31.5.3 Program

The Program AD (or designee) is responsible for developing any OSP covering a proposed operation with fissionable material. The Facility AD (or designee) must concur that the operations described in the OSP are consistent with the facility Technical Safety Requirements (TSRs) or Operational Safety Requirements (OSRs), as appropriate, and the facility safety authorization basis, that is, both the hazard analysis and accident scenarios and their associated assumptions. The process for developing safety procedures is prescribed in Chapter 2 of the Manual. Authorized users are specified by the program or facility management conducting the activity with fissionable material.

31.5.4 Hazards Control

- Hazards Control is responsible for
  - — Maintaining the criticality safety discipline at LLN.
  - — Providing criticality safety support to programs and facilities.
  - — Coordinating the annual criticality safety audit.
  - — Maintaining the Criticality Safety Group, which has knowledgeable safety professionals competent in the field of criticality safety and reports to the Department Head.

As part of the Laboratory's integrated ES&H Program, some of these criticality safety experts are assigned to support the ES&H teams.

- The Criticality Safety Group Leader is responsible for
  - — Establishing procedures to ensure the technical adequacy of the evaluation and any guidance given.
  - — Ensuring the adequacy and validity of computer codes or other information used to perform the evaluation.
  - — Making sure that evaluations and guidance are consistent with regulations, standards, and policies.

- The Criticality Safety Group is responsible for
  - — Providing training on the fundamentals of criticality safety.
  - — Supporting periodic audits and inspections of activities involving fissionable materials and maintaining a record of each audit or inspection.
  - — Evaluating and reviewing the design and installation of criticality alarm systems.
  - — Preparing criticality safety statements about LLNL's weapons, weapon components, or other items containing fissionable materials.
  - — Reviewing safety procedures.
  - — Assisting the facility staff in preparing criticality safety sections for safety procedures.
  - — Providing an emergency response and recovery support capability for incidents involving fissionable materials.
  - — Providing technical criticality safety support, including appropriate calculations and use of consensus standards or handbook guidance.
  - — Providing guidance in all aspects of criticality safety.

- The ES&H team leader is responsible for
  - — Ensuring that criticality safety evaluations of programmatic activities are conducted as required.
  - — Coordinating additional criticality safety activities in support of programs and facilities.

31.5.5 Materials Management Section

The MMS is responsible for transferring fissionable materials, other than waste, between onsite facilities and for preparing fissionable materials for offsite shipment. The MMS only releases fissionable materials to authorized receivers.

31.5.6 Assurance Review Office

The Assurance Review Office (ARO) provides an independent, internal ES&H appraisal program to assure that Laboratory ES&H policies and their implementation are consistent with Laboratory requirements, DOE orders, and ES&H regulations. The Assurance Review Office (ARO) performs an appraisal of the LLNL criticality safety program every three years.

31.5.7 Deputy Director for Operations

The Office of the Deputy Director for Operations is responsible for conducting an annual review to assess the staffing, management, and appropriate funding of the criticality safety program.

31.6 Training

Program and facility managers shall establish a program for selecting, training, and testing individuals and their functional supervisors who handle fissionable material. Training shall emphasize that workers must understand and follow applicable safety procedure requirements. All workers in nuclear facilities with the credible potential for a criticality accident shall be retrained and retested annually on emergency response procedures, including an Immediate Evacuation Exercise. Biennial training/retraining in the fundamentals of criticality safety (or equivalent), which shall be tailored to the job responsibilities, is required for

- All personnel (and their functional supervisors) who handle significant quantities of fissionable materials.
- All personnel (and their functional supervisors) who work with or design equipment or devices that contain significant quantities of fissionable materials but do not require access to such materials.
- All personnel who are permitted to work unescorted in areas where significant quantities of fissionable materials are processed or stored, even though they are not required to handle such materials.

Supervisors may, at their discretion, require additional or more frequent training.

Hazards Control offers formal training classes in the Fundamentals of Criticality Safety in accordance with ANSI/ANS-8.20. See the LLNL *Training Program Manual* for the titles and descriptions of currently available criticality safety courses.

31.7 LLNL Contacts

For additional information, contact the appropriate ES&H team or the Criticality Safety Group Leader in Hazards Control.

31.8 Supporting References and Standards

ANSI/ANS-8.1, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors."

ANSI/ANS-8.3, "Criticality Alarm System."

ANSI/ANS-8.5, "Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material."

ANSI/ANS-8.6, "Safety in Conducting Subcritical Neutron-Multiplication Measurements in situ."

ANSI/ANS-8.7, “Guide for Nuclear Criticality Safety in the Storage of Fissile Materials.”

ANSI/ANS-8.9, “Nuclear Criticality Safety Guide for Pipe Intersections Containing Aqueous Solutions of Fissile Material.”

ANSI/ANS-8.10, “Criteria for Nuclear Criticality Safety Controls in Operations with Shielding and Confinement.”

ANSI/ANS-8.12, “Nuclear Criticality Control and Safety of Homogeneous Plutonium-Uranium Fuel Mixtures Outside Reactors.”

ANSI/ANS-8.15, “Nuclear Criticality Control of Special Actinide Elements.”

ANSI/ANS-8.17, “Criticality Safety Criteria for the handling, storage, and transportation of LWR fuel outside reactors.”

ANSI/ANS-8.19, “Administrative Practices for Nuclear Criticality Safety.”

ANSI/ANS-8.20, “Nuclear Criticality Safety Training.”

ANSI/ANS-8.21, “Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors.”

DOE Memorandum, “Interpretive Guidance for DOE Order 5480.24, (Nuclear Criticality Safety)” Neal Goldenberg, Director, Office of Nuclear Safety Policy and Standards, NE-70, February 17, 1993.

DOE Memorandum, “Implementation of DOE 5490.24 (sic) Nuclear Criticality Safety at Office of Environmental Restoration and Waste Management Installation,” Lee E. Stevens, Director, Division of Regulatory Compliance, Office of Program Support, Environmental Restoration and Waste Management, EM-331, October 1, 1993.

DOE Order 232.1, “Occurrence Reporting and Processing of Operations Information,” October 30, 1995.

DOE Order 420.1, “Facility Safety,” September 30, 1995.

DOE Order 460.1, “Packaging and Transportation Safety,” September 27, 1995.

DOE Order 460.2, “Departmental Materials Transportation and Packaging Management,” September 27, 1995.

DOE Order 5480.4, “Environmental Protection, Safety, and Health Protection Standards,” May 15, 1984.

DOE Order 5480.24, “Nuclear Criticality Safety,” August 12, 1992.

DOE Order 5610.11, “Nuclear Explosive Safety,” October 10, 1990.

DOE Order 5610.12, “Packaging and Offsite Transportation of Nuclear Components, and Special Assemblies Associated with the Nuclear Explosives,” July 26, 1994.

DOE Order 6430.1A, “General Design Criteria,” April 6, 1989.

DOE Standard 3007-93, “Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities,” November 1993.

The Environment, Safety and Health Program at the Lawrence Livermore National Laboratory, Lawrence Livermore National Laboratory, Livermore, CA, Rev. 0, UCRL-AR-119618 (January 1995).

Training Program Manual, Lawrence Livermore National Laboratory, Livermore, CA , Rev. 4, UCRL-MA-106166 (November 1, 1995).

Onsite Hazardous Materials Packaging and Transportation Safety Manual, Lawrence Livermore National Laboratory, Livermore, CA, Rev. 0, UCRL-MA-108269 (September 1991).

LLNL Criticality Safety Audits, Part One: Audit Team Guidelines and *Part Two: Standards and Reference Materials*, H. F. Lutz, W. R. Harper, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-MA-110583 (September 1992).

Materials Management Material Control and Accountability Manual, Vols. I-VII (Unclassified Controlled Nuclear Information), Rev. 17, UCRL-MA-115515 (January 30, 1996).

Appendix 31-A

Terms and Definitions

authorized user	An individual within the Laboratory who is authorized to work with fissionable material in accordance with an approved safety procedure.
critical	Fulfilling the condition that a medium capable of sustaining a neutron chain reaction has an effective multiplication factor equal to unity.
critical mass	The minimum mass of fissionable material that can be made critical with a specified geometrical arrangement and material composition.
criticality	The condition of being critical.
criticality accident	The release of energy as a result of accidentally producing a self-sustaining or divergent neutron chain reaction.
criticality safety statement	A statement that lists the criteria governing criticality safety.
depleted uranium	Depleted uranium consists of elemental uranium containing less than 0.7% by weight of the fissile isotope ^{235}U. Depleted uranium is often represented by the symbol D-38 or D38.
dispersible fissionable material	(1) Any solid piece containing fissionable material with a total mass $\leq$10g. (2) Liquids, gases, solutions, slurries, powders, chips, lathe turnings, filings, hydrides, or oxides containing fissionable materials. (3) Any fissionable material carried as "box loss." (4) Other fissionable materials so defined in a safety procedure.

double-contingency principle	A nuclear criticality safety principle stating that process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible.
dynamic situation	A situation in which changes are occurring to the form and geometry of the fissionable material or its nearby surroundings. This includes moving the fissionable material within the work area. Any changes to the nearby surroundings that could affect the moderation, reflection, absorption, shielding, or escape of neutrons from the fissionable system are also included under this definition.
enriched uranium	Enriched uranium consists of elemental uranium containing more than 0.7% by weight of the fissile isotope ^{235}U. Enriched uranium is often identified as Low Enriched Uranium (LEU), Intermediate Enriched Uranium (IEU), Highly Enriched Uranium (HEU), or Oralloy (Oy).
fissile materials	Fissionable isotopes capable of sustaining a neutron chain reaction induced by neutrons of any energy (including thermal or low energy neutrons). Fissile isotopes include ^{233}U, ^{235}U, ^{239}Pu, and ^{241}Pu.
fissionable materials	Isotopes capable of fission induced by neutrons of some energy.
functional supervisor	The person designated by management to be the day-to-day supervisor of an authorized employee. For an authorized employee assigned a specific, short-term assignment in an area, this may be the payroll supervisor. Authorized employees assigned duties in more than one area may have more than one functional supervisor. The functional supervisor shall ensure that the authorized employee is trained and qualified to perform assigned tasks.

multiplication factor (k)	The ratio of the total number of neutrons produced during a time interval (excluding neutrons produced by sources whose strengths are not a function of fission rate) to the total number of neutrons lost by absorption and leakage during the same interval. When the quantity is evaluated for an infinite medium or for an infinite repeating lattice, it is referred to as the infinite multiplication factor (k_∞). When the quantity is evaluated for a finite medium, it is referred to as the effective multiplication factor (k_{eff}).
natural uranium	Natural uranium consists of elemental uranium containing 0.7% by weight of the fissile isotope ^{235}U. Natural uranium is also known as tube alloy and may be represented by the symbol Tu.
nondispersible fissionable material	Fissionable materials that do not meet the definition of dispersible fissionable material.
nuclear criticality safety	Protection against the consequences of a criticality accident preferably by prevention of the accident.
safety procedure	A formal (i.e., written, reviewed, and approved) document describing procedures, controls, and limits for operations involving fissionable materials and other hazardous operations.
significant quantity of fissionable material	Minimum mass of fissionable material for which control of at least one parameter is required to ensure subcriticality under all normal and credible abnormal conditions.
static situation	A situation in which no changes are occurring to the form and geometry of the fissionable material or its nearby surroundings.
subcritical assembly	An assembly of materials in which a fission chain reaction can be sustained only by adding neutrons from an independent source.

supercritical system	A system that contains fissionable material in which the neutron population (and associated fission power level) increases exponentially with time.
workstation	For the purposes of criticality safety, an enclosure, assembly table, or specific item of equipment with spatial boundaries that are well defined by physical barriers or administratively specified barriers.